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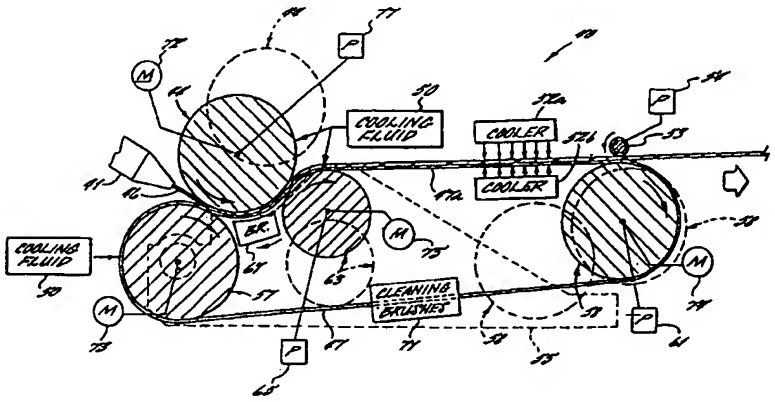


(57) Abstract

An apparatus (40) for making a lenticular screen includes a rotating lenticular pattern forming roll (44) downstream from an extruder (41), and a conveyor belt (47) for pressing the hot plastic sheet (46) against the lenticular pattern forming roll (44) to form the lenticular pattern in the hot plastic sheet (46). The apparatus (44) preferably permits adjusting a tension of the conveyor belt (47) to thereby adjust a pressure applied to the hot plastic sheet (46), and permits adjusting a length of contact of the hot plastic sheet (46) around a periphery of the rotating lenticular pattern forming roll (44). The lenticular pattern forming roll (44) is preferably a chill roll for receiving a cooling fluid to cool the hot plastic sheet (46). The conveyor belt (47) may also be configured to include a flat portion (47a) downstream from the rotating lenticular pattern forming roll (44) for providing a flat surface during cooling of the hot plastic sheet (46). The apparatus (40) may include a frame carrying the lenticular pattern forming roll (44), a first belt support roll (57) positioned adjacent the lenticular pattern forming roll (44), and a second belt support roll (58) spaced from the first belt support roll (57). Accordingly, a positioner (61) may be associated with the second belt support roll (58) for adjusting a tension of the conveyor belt (47). A third belt support roll (63) may be positioned adjacent the lenticular pattern forming roll (44), and between the first and second belt support rolls (57, 58) and be positioned for adjusting a length of contact of the hot plastic sheet (46) around a periphery of the rotating lenticular pattern forming roll (44).

APPARATUS FOR FORMING A LENTICULAR SHEET AND ASSOCIATED METHODS

Field of the Invention

The present invention relates to the field of machinery and processes, and, more particularly, to an apparatus and methods for producing lenticular screens.

Background of the Invention

In lenticular imaging, an optical element called a lenticular screen is placed between an image and the viewer, as disclosed, for example, in U.S. Patent Nos. 3,504,059 to Glenn, Jr.; 2,724,312 to Gruetzner; and 3,683,773 to Dudley. Lenticular screens are typically formed from a transparent plastic sheet with lenses integrally formed on only one side that focus on the opposite and typically flat side. The lenticular elements can have many shapes, such as, for example, cylindrical, angular, spherical, or shaped like cube corners.

The original lenticular image can be created photographically, electronically or by a combination of both. Images can be reproduced and mass produced using photo-sensitive materials, printed by lithographic means or by other means of printing or transfer of inks or dyes. Electronic displays, such as cathode-tubes or flat panel displays, may also be fitted with a lenticular screen if the resolution of the display is sufficient.

One known technique for manufacturing lenticular screens includes cutting the lenticular lens pattern directly into transparent plastic materials. A lenticular screen can also be formed by the casting of thermosetting resins onto flat forms including the lenticular lens pattern. In addition, a lenticular screen may also be made by thermoforming a cast or extruded transparent sheet by heat and pressure between one polished plate and one plate with the lenticular pattern cut or engraved into its surface. Injection molding may also be used to form a lenticular screen.

The three roll polishing stack **22** is basically a simplified calendar. The polishing rolls **23, 24** and **25**, are also known as chill rolls in flat plastic sheet production or as embossing rolls, if a pattern is cut or engraved into their surface. The functions of the rolls are to give the sheet, which initially is pre-formed by the sheet die at the end to the extruder **21**, a more uniform gage, polish the sheet surface, transfer the pattern of the embossing roll to the sheet, and chill the material to a temperature lower than its softening point to keep the sheet in the shape formed by the rolls. The embodiment of the prior art machine **20'** of FIG. 2 illustrates that the rolls **23', 24'** and **25'** can be arranged in a diagonal orientation. Of course a horizontal orientation is also possible.

Considering the arrangement of FIG. 1, if the three rolls in the stack **22** have one common motor drive, the upper roll **23** and middle roll **24** are held in position so they define a nip point therebetween. The lower roll **25** is held within a short distance to the middle roll **24**, since the plastic is shrinking, and therefore the circumferential speed of the rolls needs to be differentiated. The plastic web **26** is taken away by the pull rolls **28** to keep the sheet in relative contact with the surface of the middle and lower rolls, but will also apply extra tension to the plastic web **26** as well. The tension caused by the pull rolls **28** will stretch the material.

In the case of individual drives for each of the rolls in the stack **22'** shown in FIG. 2, the upper roll **23'** can also form a nip with the middle roll **24'**; however, its speed has to be slightly different to keep the plastic web **26'** in contact with the middle roll. In addition, pull rolls, not shown, still have the task

an accurate reproduction of the lens pattern. The thicker the sheet, the greater the problem with accurately reproducing the lenticular pattern. Some materials can, if cooled too quickly, leave a residue on the rolls, which if allowed to build up, would prevent the lenticular pattern from being accurately reproduced in the plastic. Accordingly, the machine is taken out of service and the residue removed, thereby resulting in a loss of production.

Summary of the Invention

In view of the foregoing background, it is therefore an object of the invention to provide an apparatus and associated method for efficiently and accurately making a lenticular screen, and while accounting for shrinkage and other properties of the plastic material.

This and other objects, advantages, and features of the present invention are provided by an apparatus for making a lenticular screen comprising a rotating lenticular pattern forming roll downstream from an extruder, and a conveyor belt for pressing the hot plastic sheet against the lenticular pattern forming roll to form the lenticular pattern in the hot plastic sheet. The apparatus preferably includes tension adjusting means for adjusting a tension of the conveyor belt to thereby adjust a pressure applied to the hot plastic sheet. In addition, the apparatus preferably further comprises contact adjusting means cooperating with the conveyor belt for adjusting a length of contact of the hot plastic sheet around a periphery of the rotating lenticular pattern forming roll. Accordingly, the dwell time of the hot plastic sheet on the lenticular pattern forming roll can be controlled, along with the pressure applied to the hot plastic sheet.

Other aspects of the present invention relate to cooling of the plastic sheet after the lenticular

embodiment for adjusting the contact time of the hot plastic sheet on the lenticular pattern forming roll. One or more additional bearings may be provided to press the underside of the belt and thereby press the plastic sheet against the lenticular pattern forming roll. In addition, the second and third belt support rolls are also preferably arranged to define the flat portion of the conveyor belt downstream from the rotating lenticular pattern forming roll, and the flat portion may be horizontally oriented.

The conveyor belt itself preferably has a relatively smooth surface to thereby form a corresponding smooth surface on the reverse side of the plastic sheet. In one embodiment, the conveyor belt may comprise a metal fabric. One or more brushes may be positioned to clean the surface of the belt.

A method aspect of the present invention is for making a screen having a predetermined pattern thereon, such as for making a lenticular pattern when using a lenticular pattern forming roll. The method preferably comprises the steps of: extruding a hot plastic sheet; positioning a rotating pattern forming roll downstream from the extruder; and using a conveyor belt for pressing the hot plastic sheet from the extruder against the pattern forming roll to form a pattern in the hot plastic sheet.

The method also preferably further comprises the steps of: adjusting a tension of the conveyor belt to thereby adjust a pressure applied to the hot plastic sheet, and/or adjusting a length of contact of the hot plastic sheet around a periphery of the rotating pattern forming roll. The method may also include the step of configuring the conveyor belt to include a flat portion downstream from the rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the pattern is formed therein.

Brief Description of the Drawings

sleeve from the mandrel in accordance with the present invention.

FIG. 8E is a perspective view of the lenticular sleeve being installed onto a chill roll in accordance with the present invention.

FIG. 9 is a flowchart of the method steps for making the lenticular pattern forming roll in accordance with the present invention.

FIGS. 10A-10D are cross-sectional views illustrating conversion of the lenticular sleeve into a flat lenticular form in accordance with the invention.

Detailed Description of the Preferred Embodiments

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Thicknesses of layers are exaggerated for clarity. Like numbers refer to like elements throughout.

Referring initially to FIGS. 3-7, the apparatus **40** for making a lenticular screen is first described. The apparatus **40** includes a rotating lenticular pattern forming roll **44** downstream from an extruder **41**, and a conveyor belt **47** for pressing the hot plastic sheet **46** against the lenticular pattern forming roll to thereby form the lenticular pattern in the hot plastic sheet. The apparatus **40** preferably includes tension adjusting means for adjusting a tension of the conveyor belt **47** to thereby adjust a pressure applied to the hot plastic sheet. In addition, the apparatus **40** preferably further comprises contact adjusting means cooperating

upper cooler **52a** may direct cooling air onto the plastic sheet **46**, and while the lower cooler directs air upward onto the back side of the conveyor belt **47** as would be readily understood by those skilled in the art. The air coolers could be replaced by water or other heat exchangers as would be understood by those skilled in the art. The time/temperature profile of cooling may be thus readily controlled to ensure a high quality lenticular screen.

Also relating to handling of the sheet **46** during cooling, the apparatus **40** illustratively includes at least one passive sheet guide roll **53** positioned opposite the conveyor belt **47** and downstream from the lenticular pattern forming roll **44** to guide the hot plastic sheet on the conveyor belt without imparting undesirable tension to the sheet, in contrast to the conventional puller rolls **28** (FIG. 1). The illustrated passive guide roll **53** is a rubber coated roll, although those of skill in the art will recognize that other types and compositions of rolls may also be used. The passive guide roll **53** may be positioned by a positioner **54**, such as may be provided by swing-arms and pneumatic cylinders, or other arrangements with linear motion and hydraulics or mechanical positioning as would be readily understood by those skilled in the art. The passive guide roll **53** is positioned over the second belt support roll **58** so that the sheet **46** is pulled from the apparatus **40** along a line parallel to the flat conveyor belt portion **47a**. The passive guide roll **53** is only driven by the friction between itself, the plastic sheet **46** and the belt **47**. Pressure on the passive guide roll **53**, to ensure sufficient friction, can be applied mechanically or by pneumatic or

61 may be hydraulic, pneumatic, or electrically operated as would be understood by those skilled in the art without further explanation herein.

The apparatus 40 also illustratively includes a third belt support roll 63 carried by the frame 55 and positioned adjacent the lenticular pattern forming roll 44 and between the first and second belt support rolls 57, 58, respectively. Accordingly, another positioner 65 may be associated with the third belt support roll 63 for adjusting a length of contact of the hot plastic sheet 46 around a periphery of the rotating lenticular pattern forming roll 44. The positioner 65 may include swing arms and motorized screws, but mechanical guides like curved or straight linear guides and other mechanical means for positioning that provide the same functions are also contemplated by the present invention. Considered in somewhat different terms, control of the position of third roll 63 provides one embodiment for adjusting the contact time and extent of the hot plastic sheet 46 on the lenticular pattern forming roll 44. Those of skill in the art will appreciate that the relative positioning of the first belt support roll 57, the lenticular pattern forming roll 44, and the third roll 63 define the contact of the hot plastic sheet 46 with the lenticular pattern forming roll.

One or more additional bearings 67 may be provided to press the underside of the conveyor belt 47 and thereby press the plastic sheet 46 against the lenticular pattern forming roll 44 (FIG. 4). For special applications where continued high pressure higher than the tensioning of the belt 47 can apply, an arrangement with needles, such as needle bearings, may

life compared to conventional polishing rolls, for example.

Some or all of the rolls **44**, **57**, **58** and **63** may be driven by electric motors **72**, **73**, **74** and **75**, respectively, as schematically illustrated in FIG. 4. In other embodiments, some of the rolls may be passively driven as will also be readily appreciated by those skilled in the art. As depicted in the illustrated embodiment, a positioner **77** may be operatively connected to the lenticular pattern forming roll **44** to control its relatively position, such as to move it between engaged and retracted positions. The positioner **77** may include swing arms and associated hydraulic cylinders, for example, but other arrangements with linear guides, and/or pneumatic or mechanical positioning are also contemplated by the present invention.

The outer surfaces of the rolls **57**, **58** and **63** may preferably be hardened for durability. These rolls are desirably ground parallel within the tolerances normal for the plastic extrusion industry, but do not necessary need to have a fine surface as provided by polishing. Instead, their surface roughness will somewhat depend on the hardness and thickness of the belt **47**. The rolls **57**, **58** and **63** and any other rolls that will be in contact with the back of the belt **47** will be cheaper to manufacture, because they do not need the true mirror surface required in conventional polishing stacks. For enhanced friction, the first and second belt support rolls **57**, **58** and/or the third belt support roll **63** may be coated with a hard polyurethane rubber or other appropriate rubber material.

The apparatus **40** offers a number of important advantages including easy start-up, since no supporting reproduced sheet has to be thread trough the machine

47 to thereby adjust a pressure applied to the hot plastic sheet 46, and/or adjusting a length of contact of the hot plastic sheet around a periphery of the rotating pattern forming roll 44. The method may also include the step of configuring the conveyor belt to include a flat portion 47a downstream from the rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet 46 after the pattern is formed therein. Accordingly, the plastic sheet 46 may be formed to be relatively flat as is desirable for many applications.

Referring now more particularly to FIGS. 5-7 another aspect of the invention is explained. The first belt support roll 57 may be a chill roll comprising a tubular body 57a through which the cooling fluid is passed. In addition, the third belt support roll 63 may also be a chill roll comprising a tubular body 63a through which cooling fluid is also passed as would be readily understood by those skilled in the art. Of course, in other embodiments either or both of these rolls may not need the cooling fluid.

As shown in FIGS. 5 and 6, the lenticular pattern forming roll 44 may comprise a tubular body defining a chill roll 44a and a lenticular sleeve 44b positioned on the chill roll. The lenticular sleeve 44b has a lenticular pattern formed on an outer surface for forming the corresponding lenticular pattern in the plastic sheet 46. The sleeve 44b may be readily manufactured and transported to a desired location to be installed on the chill roll 44a. The lenticular sleeve 44b may also be removed from the chill roll 44a and transported for resurfacing and without requiring transporting of the entire chill roll. Accordingly, considerable savings may be realized. In addition, a

prepared, such as by polishing to define a desired surface (FIG. 8A). The amorphous nickel-phosphorous metal layer **81** is deposited onto the mandrel **80** using either an electroless or electrodeposition technique as would be readily appreciated by those skilled in the art. At Block **98** and as shown schematically in FIG. 8C, the lenticular pattern is cut into the outer surface of the metal layer **81** by the illustrated diamond cutter **84** while on the mandrel **80** to form the lenticular sleeve **44b**. At Block **100**, the thus formed lenticular sleeve **44b** is removed or freed from the mandrel as shown in FIG. 8D. The lenticular sleeve **44b** may be freed from the mandrel **80** by the injection of air or another fluid into the interface between the sleeve and mandrel. Alternately, a difference in coefficients of thermal expansion may be used to separate the sleeve and mandrel as would be readily appreciated by those skilled in the art. In other words, cooling or heating may be used to separate the sleeve **44b** from the mandrel **80**.

The lenticular sleeve **44b** may typically be shipped to the location making the lenticular screen as set forth in Block **102**. Because of the relatively high cost of the capital equipment for forming the lenticular pattern, the forming or a similar refinishing process is likely to only be performed at certain locations suitably equipped as would be understood by those skilled in the art. The lenticular sleeve **44b** may be installed onto the chill roll **44a** (Block **104**) as shown in FIG. 8E before the process ends (Block **106**).

The step of installing the lenticular sleeve **44b** onto the chill roll **44a** may also be aided by the injection of air or other fluid into the interface

The inventor of the present invention previously developed chemistry and methods for making relatively thick deposits (50 to 500 micron) of amorphous nickel-phosphorous with 13 to 15% phosphorous content (by weight) by electroless depositing. At present, amorphous nickel-phosphorous compositions with even higher phosphorous content can also be deposited by electrodepositing as would be readily understood by those skilled in the art. Although the mechanism is not entirely understood, tool wear is minimized when the phosphorus content of the deposit is greater than about 11% (by weight). Accordingly, the nickel-phosphorous has good lubricating properties which makes it well suited for tools used in the forming of plastics.

Both the electroless and electrodeposited nickel-phosphorous alloys can be used for the lenticular sleeve **44b**, but the electrodeposited may have some advantages. Electrodeposition may be at a rate of up to 60 microns per hour and a phosphorous content of higher than about 15% can be obtained. Another advantage of the electrodeposited nickel-phosphorous composition is the consistently higher density as compared to the electroless deposited material. It is believed without applicant being bound thereto that the electrodeposited nickel-phosphorous alloys contain a lower void volume than the electroless deposited alloys, that is, the nickel and phosphorous are more closely packed. This reduces the porosity in the plated deposit and is of particular interest for diamond machining applications since it potentially leads to fewer micro defects in the material being machined, thereby resulting in improved surface finish. In addition, electrodeposited Ni-P can have a hardness of Rockwell C 45-51 as deposited, and by heat treatment can reach a hardness of Rockwell C 70-72. This

According to another aspect of the invention and as shown with additional reference to FIGS. 10A-10D, the lenticular sleeve **44b** (FIG. 10A) can be split or cut axially to produce the structure **44b'** shown in FIG. 10B, then straightened to the intermediate structure **44"** shown in FIG. 10C, to finally become a flat form structure **44"'** as shown in FIG. 10D to be used for casting, injection molding or thermoforming of lenticular screens. Flat lenticular forms have traditionally been cut into sheets, which can be both difficult and costly. In contrast, the axial splitting of the lenticular sleeve **44b** in accordance with the invention can provide a flat lenticular form **44'''** relatively easily and economically.

As long as the outer or mantel surface of the chill roll **44a**, to be used with the lenticular sleeve **44b** is not damaged in any way, the roll itself need not be resurfaced when the lenticular sleeve is exchanged. Many different lenticular screens are commonly desired and the ability to reuse the same chill roll **44a** (or a pair for speedy exchange) enable more economical production of shorter runs, and allow for special lenticular lenses, as compared to dedicated rolls with the lenticular pattern in the outer surface. The cutting of the lenticular pattern may also take place on extremely accurate machines in accordance with the invention. The lenticular sleeve **44b** enables less weight to be manipulated during cutting as would be readily appreciated by those skilled in the art. Less weight to be handled during cutting results in one or both of easier cutting and higher accuracy.

The following table, formulas, derivations and calculations show that it is possible for the nickel-phosphorous lenticular sleeve **44b** to be fitted onto a chill roll **44a** to produce a lenticular pattern forming

and the chill roll. Pt is given below and where L is length of the sleeve, and f is coefficient of friction between the sleeve and the chill roll:

$$Pt=\frac{5,000/f}{\pi Dt\cdot L}\approx\frac{5,000}{\pi DLf} \qquad <1>$$

$$2Nmax=\int_{\cdot}^{\pi} PtL\cdot\frac{Dt}{2}\cdot\sin\propto\cdot d\propto \qquad <2>$$

$$=Dt\cdot L\cdot Pt$$

At temperature t, the maximum stress in the sleeve will be (Pt is also imparting stress to the sleeve, but that is small enough to be neglected) and tm is the thickness of Ni-P sleeve:

$$\sigma max(t)=\frac{Nmax}{L\cdot tm}=\frac{5,000}{2\pi f\cdot L\cdot tm}$$

Supposing now that the inside diameter of the sleeve at temperature t is dt, (when it is free), then the mean diameter will be dt + tm. Under a stress of σmax the sleeve will expand to an inside diameter of Dt, and a mean diameter of Dt+tm. The expanded length is, where E is Young's modulus of the sleeve:

$$\begin{aligned}\Delta Lt&=\pi(Dt+tm)-\pi(dt+tm)\\&=\pi(Dt-dt)\end{aligned}$$

but:

$$\begin{aligned}\Delta Lt&=\pi[(D-d+\Delta T(D\cdot Coer-d\cdot Coes)]\\Lt&=\pi(dt+tm)\\&=\pi[d(1+\Delta TCoes)+tm]\end{aligned}$$

$$\frac{D-d+\Delta T(D\cdot Coer-dCoes)}{d(1+\Delta T\ Coes)+tm}=\frac{5,000}{2\pi f\cdot L\cdot tmE}$$

From the above equations, we can find the value of d. The pressure needed to expand the sleeve from an inside diameter of D+ δ at 20°C:

$\Delta L=\pi(D+\delta-d)$

descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the lenticular pattern is formed therein and without imparting tension thereto.

8. An apparatus according to Claim 1 further comprising:

a frame carrying said lenticular pattern forming roll;

a first belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll; and

a second belt support roll carried by said frame and spaced from said first belt support roll.

9. An apparatus according to Claim 8 further comprising a positioner associated with said second belt support roll for adjusting a tension of said conveyor belt.

10. An apparatus according to Claim 8 further comprising:

a third belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll and between said first and second belt support rolls; and

a positioner associated with said third belt support roll for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

11. An apparatus according to Claim 6 wherein said second and third belt support rolls are arranged to define a generally horizontal flat portion of said conveyor belt downstream from said rotating lenticular pattern forming roll.

12. An apparatus according to Claim 1 wherein said conveyor belt has a relatively smooth surface to thereby form a corresponding smooth surface in the plastic sheet.

roll and between said first and second belt support rolls; and

a positioner associated with said third belt support roll for adjusting a length of contact of the hot plastic sheet around a periphery of said rotating lenticular pattern forming roll.

19. An apparatus according to Claim 14 wherein said conveyor belt comprises a flat portion downstream from said rotating lenticular pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the lenticular pattern is formed therein.

20. An apparatus according to Claim 19 further comprising cooling means positioned adjacent said flat portion of said conveyor belt for cooling the hot plastic sheet after the lenticular pattern is formed therein.

21. An apparatus according to Claim 14 wherein said lenticular pattern forming roll comprises means for receiving a cooling fluid therein to cool the hot plastic sheet.

22. An apparatus according to Claim 14 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the lenticular pattern is formed therein and without imparting tension thereto.

23. An apparatus for making a lenticular screen comprising:

a rotating lenticular pattern forming roll downstream from an extruder;

a conveyor belt for pressing a hot plastic sheet from the extruder against said lenticular pattern forming roll to form a lenticular pattern in the hot plastic sheet and define the lenticular screen; and

for receiving a cooling fluid therein to cool the hot plastic sheet.

29. An apparatus according to Claim 23 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from said lenticular pattern forming roll to guide the hot plastic sheet on said conveyor belt after the lenticular pattern is formed therein and without imparting tension thereto.

30. An apparatus for making a lenticular screen comprising:

a rotating lenticular pattern forming roll downstream from an extruder; and

a conveyor belt for pressing a hot plastic sheet from the extruder against said lenticular pattern forming roll to form a lenticular pattern in the hot plastic sheet and defining the lenticular screen;

said conveyor belt comprising a flat portion downstream from said rotating lenticular pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the lenticular pattern is formed therein.

31. An apparatus according to Claim 30 further comprising:

a frame carrying said lenticular pattern forming roll;

a first belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll;

a second belt support roll carried by said frame and spaced from said first belt support roll; and

a third belt support roll carried by said frame and positioned adjacent said lenticular pattern forming roll and between said first and second belt support rolls to thereby define the flat portion of said conveyor belt downstream from said rotating lenticular pattern forming roll.

39. An apparatus according to Claim 35 wherein said conveyor belt comprises a flat portion downstream from said rotating pattern forming roll and providing a flat surface during cooling of the hot plastic sheet after the pattern is formed therein.

40. An apparatus according to Claim 39 further comprising cooling means positioned adjacent said flat portion of said conveyor belt for cooling the hot plastic sheet after the pattern is formed therein.

41. An apparatus according to Claim 35 wherein said pattern forming roll comprises means for receiving a cooling fluid therein to cool the hot plastic sheet.

42. An apparatus according to Claim 35 further comprising at least one passive sheet guide roll positioned opposite said conveyor and downstream from said pattern forming roll to guide the hot plastic sheet on said conveyor belt after the pattern is formed therein and without imparting tension thereto.

43. An apparatus according to Claim 35 further comprising:

a frame carrying said pattern forming roll;

a first belt support roll carried by said frame and positioned adjacent said pattern forming roll; and

a second belt support roll carried by said frame and spaced from said first belt support roll.

44. An apparatus according to Claim 43 further comprising a positioner associated with said second belt support roll for adjusting a tension of said conveyor belt.

45. An apparatus according to Claim 43 further comprising:

a third belt support roll carried by said frame and positioned adjacent said pattern forming roll and between said first and second belt support rolls; and

a positioner associated with said third belt support roll for adjusting a length of contact of the

least one cooler adjacent the flat portion of the conveyor belt downstream from the rotating pattern forming roll.

53. A method according to Claim 47 further comprising the step of passing a cooling fluid through the rotating pattern forming roll to cool the hot plastic sheet.

54. A method according to Claim 47 further comprising the step of providing at least one passive sheet guide roll positioned opposite the conveyor and downstream from the pattern forming roll to guide the hot plastic sheet on the conveyor belt after the pattern is formed therein and without imparting tension thereto.

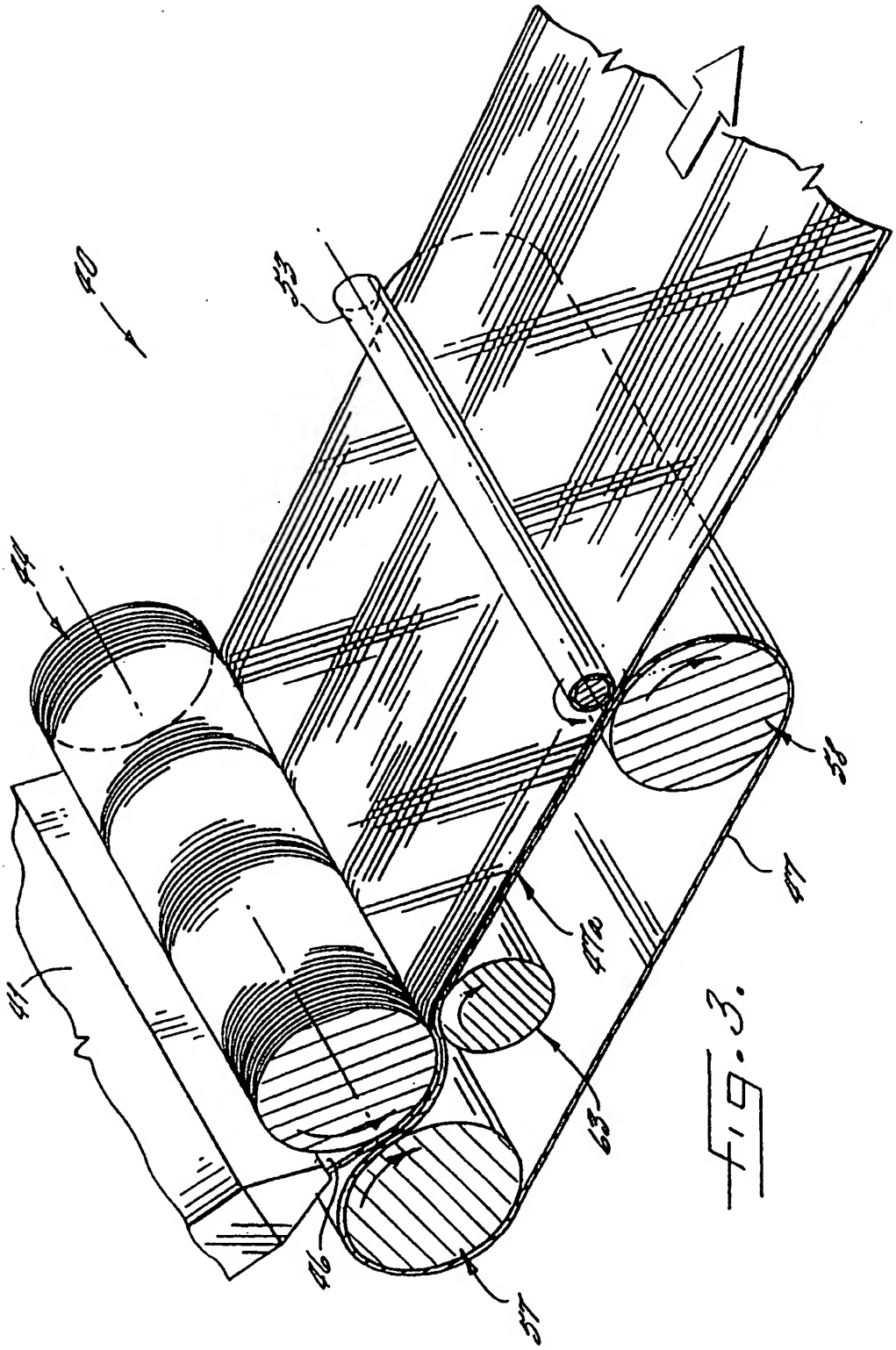


FIG. 3.

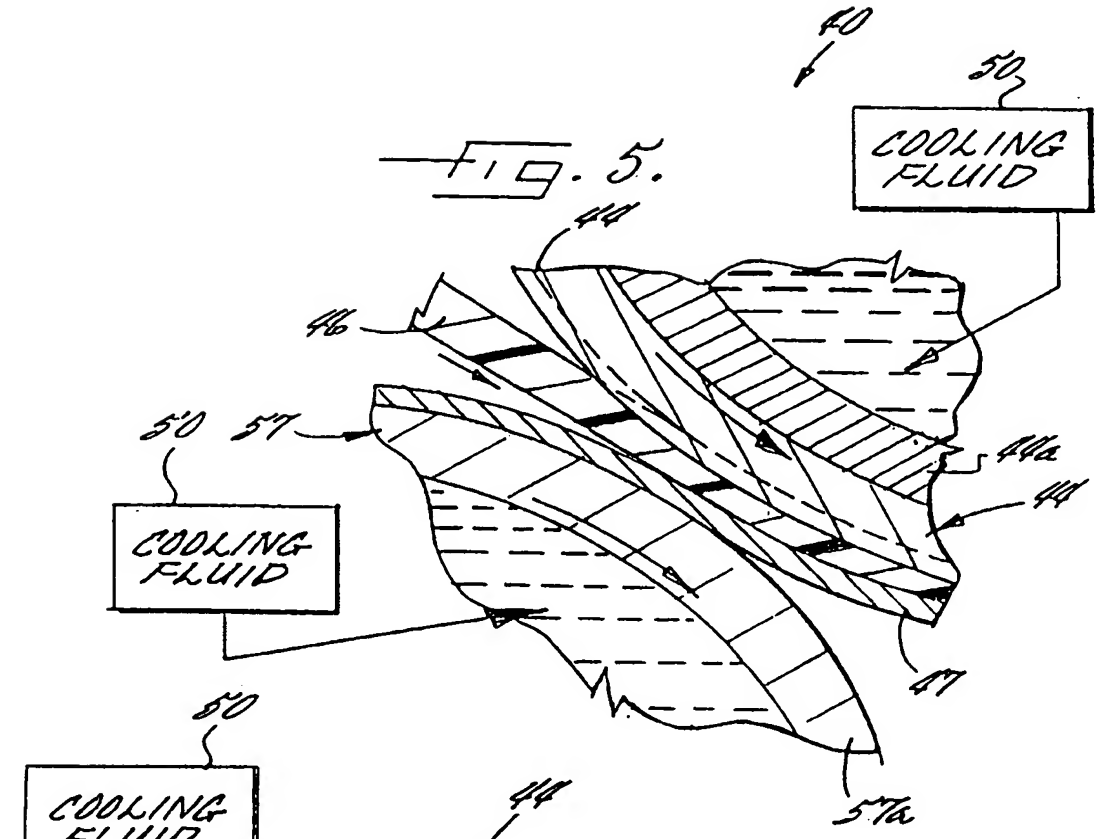
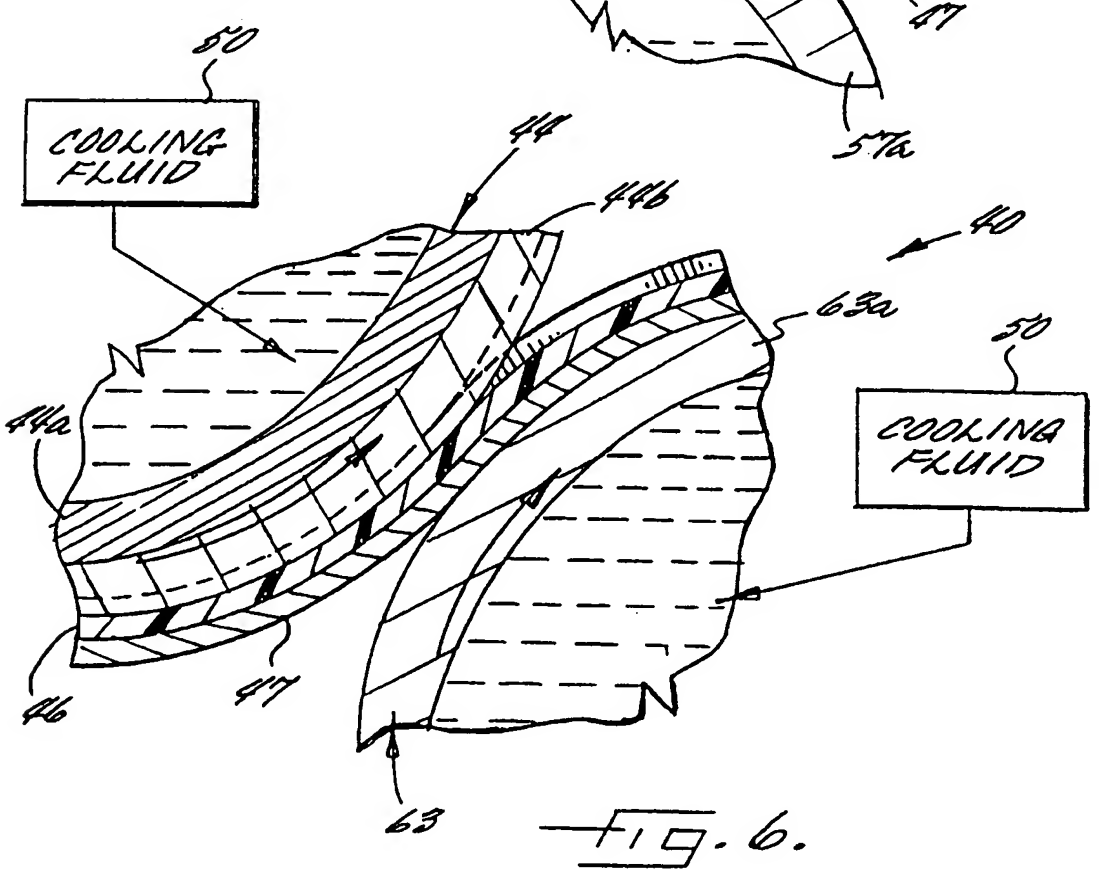

40
50
COOLING FLUID
44
46
50
57
COOLING FLUID
44a
44
47
57a

FIG. 5.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44a
40
63a
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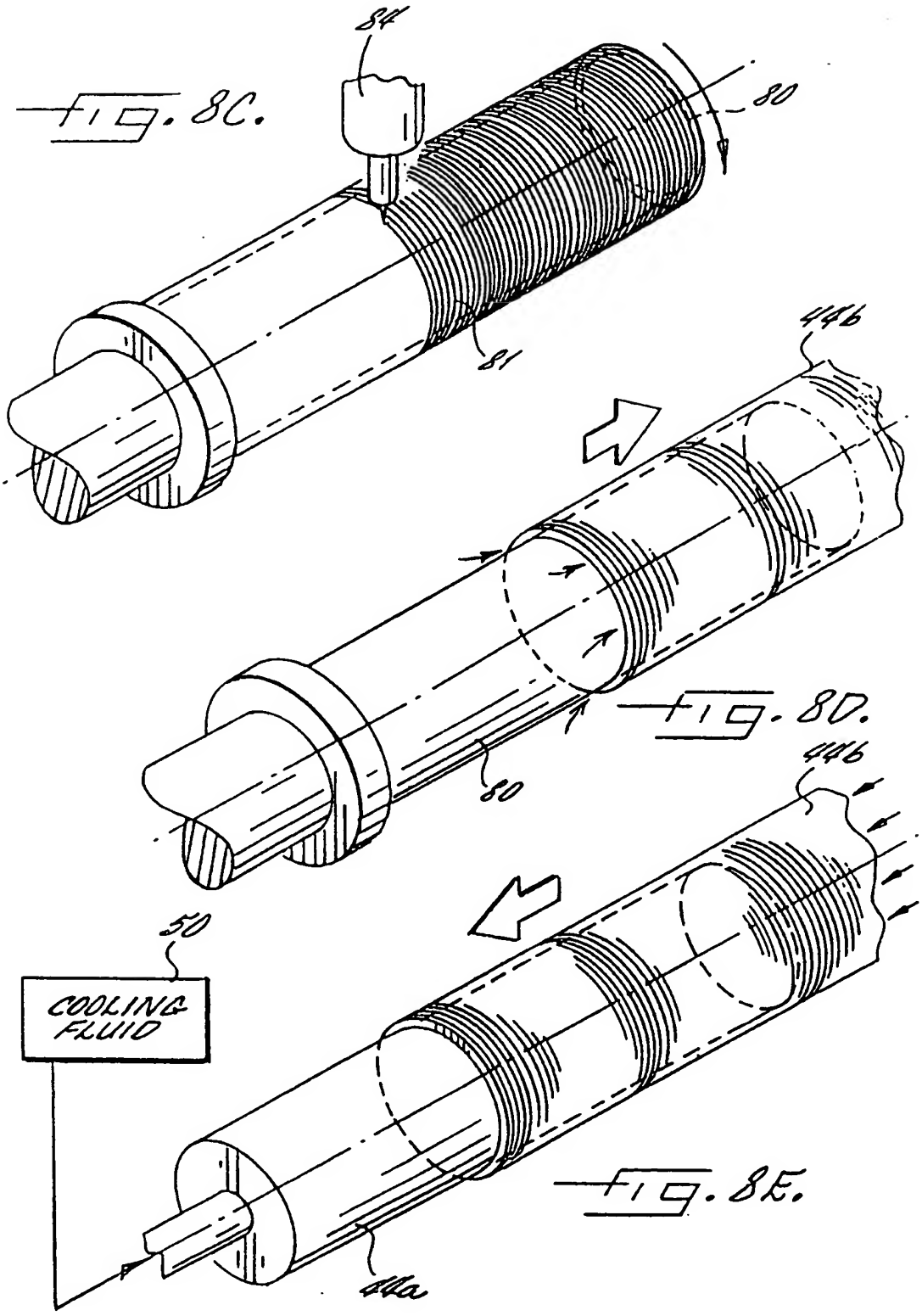
COOLING FLUID
46
47
63

FIG. 6.


84
80
81
FIG. 8C.
446
80
FIG. 8D.
446
50
COOLING FLUID
446a
FIG. 8E.

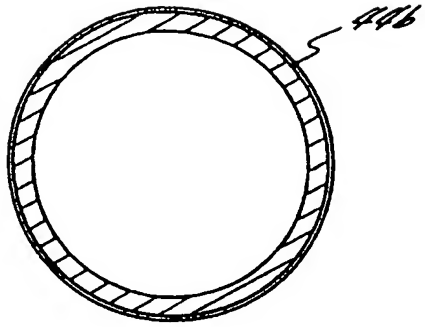


Fig. 10A.

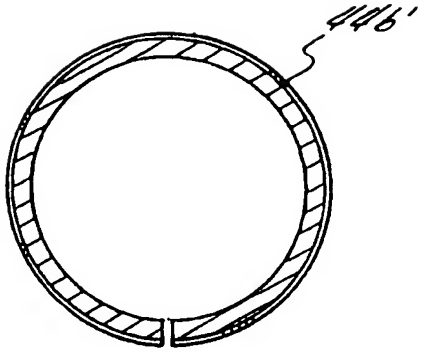


Fig. 10B.

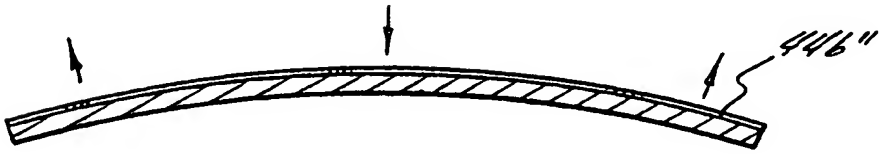


Fig. 10C.

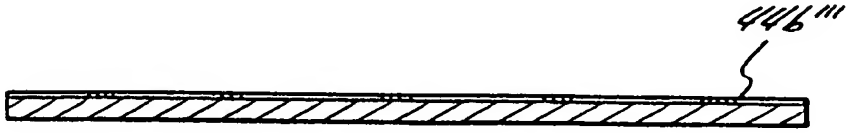


Fig. 10D.

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 98/18717

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 050 (M-120), 3 April 1982 & JP 56 164826 A (DAINIPPON PRINTING CO LTD), 18 December 1981 see abstract	1-54
A	US 2 964 251 A (M. L. SAMUELS ET AL) 13 December 1960 see claim 1; figures 1-6	6,21,28, 33,53
A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 042, 16 March 1982 & JP 56 159039 A (DAINIPPON PRINTING CO LTD), 8 December 1981 see abstract	1-54
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 282 (M-1269), 23 June 1992 & JP 04 071897 A (DAINIPPON PRINTING CO LTD), 6 March 1992 see abstract	1-54
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 283 (C-0955), 24 June 1992 & JP 04 074864 A (MATSUSHITA ELECTRIC IND CO LTD), 10 March 1992 see abstract	1-54

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